

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B71 02022

SUBJECT: Effect of Launch Azimuth on  
SPS ΔV Requirements and Launch  
Vehicle Capability - Case 310

DATE: February 11, 1971

FROM: R. A. Bass  
S. F. Caldwell

ABSTRACT

The reduced S-IVB propellant required to achieve earth orbit as launch azimuth approaches 90° allows a 90° launch to yield an 865 lbs higher payload capability than a 72° launch. This payload gain must be tempered with the probable increase in translunar energy requirements as launch azimuth increases. Higher translunar energies require more S-IVB propellant at TLI and thus reduce the payload capability; average payload loss is 3.0 lbs/degree ( $\sigma = 3.0$  lbs/degree). Considering both EOI and TLI effects the net gain for a 90° launch azimuth over a 72° azimuth would be 811 lbs.

Missions designed for a 72° to 96° launch window were examined for five candidate lunar landing sites, Descartes, Hadley, Marius Hills, Davy Carter Chain and Copernicus for the fifteen months than encompass the J-mission sequence. Over 80% of the cases showed the TLI energy requirement highest at an azimuth other than 72°. The largest increase in the launch vehicle TLI energy requirement across the launch window (72° to 96°) was equivalent to a payload capability decrease of 363 pounds; the average payload decrease was 90 pounds.

The SPS ΔV requirements also generally increase with launch azimuth; end-of-mission contingency ΔV reserves decrease about 2.2 fps per degree of azimuth change ( $\sigma = 4.3$  fps/degree). The minimum available contingency ΔV from the SPS occurred at an azimuth other than 72° in nearly two-thirds of the mission sampled. The worst case was 463 fps lower than the ΔV available with a 72° launch azimuth.

Missions designed for a launch window based on an azimuth range of 80° to 100° should show similar sensitivities in both SPS performance and TLI energy requirements.

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ON SPS DELTA V REQUIREMENTS AND LAUNCH  
VEHICLE CAPABILITY (Bellcomm, Inc.) 29 p

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MEMORANDUM FOR FILE

Preliminary evaluations of mission feasibility usually only consider missions launched at the launch azimuth at the opening of the window, 72°. Effects of higher launch azimuths are normally examined in later mission analysis work. These effects have been examined for a representative sample of missions in order to provide an insight into the magnitude of the change in SPS contingency ΔV and the launch vehicle requirements across the launch window. Frequency distributions for the changes in both the SPS contingency ΔV available and the translunar injection (TLI) energy requirements as launch azimuth increases through the 72° to 96° range are presented. The rate of change of both these parameters with launch azimuth is examined to determine both magnitude and direction of change.

Data Base

Optimized missions with a 72° launch azimuth were found for each of five landing sites, Descartes, Hadley, Marius Hills, Davy Crater Chain and Copernicus, in each month from July 1971 through September 1972. Examination of the available contingency ΔV for each mission showed seven cases (Marius Hills - 11/71-3/72 and Hadley 11/71-12/71) where the SPS available ΔV was less than -200 fps and relaxation of any or all possible mission design constraints would probably not result in a feasible mission.\* These cases were removed from the sample. Then, using the approach azimuth at the landing site found optimum for the 72° launch azimuth, missions launched with 80°, 90° and 96° azimuths were simulated. In these simulations the sun elevation was allowed to optimize between 8° and 12°. Sun elevation generally increased with launch azimuth until the 12° limit was reached.

The simulations are summarized in the Appendix along with the mission design constraints and the spacecraft weight model employed.

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\*A minimum of 250 fps available ΔV is required for the weather avoidance contingency.

Results

## • Launch Vehicle Requirements

The reduction in earth orbit insertion requirements as launch azimuth approaches 90° predominates over the changes in translunar insertion energy requirements caused by launch azimuth variation. Figure 1\* illustrates the payload gain due only to the reduced EOI requirements for azimuths near 90°. This curve peaks at a gain of 870 lbs near 91° launch azimuth.

Launch vehicle capability will decrease an average of 3.0 lbs/degree considering only the increase in TLI energy requirement. The largest loss in launch vehicle capability due to increased TLI energy requirements to occur through a launch window was 363 lbs. This case was one of the 66% that decreased continually as the launch azimuth increased. Four percent of the cases showed a continual improvement in launch capability through the window; 12% showed a minimum at an intermediate azimuth and the rest a maximum. A majority of these last two classifications showed the extremes at a 90° azimuth. Greater than 80% showed the highest TLI energy requirement at an azimuth above 72°. The average energy requirement increase of the 80% showed an equivalent decrease of 90 lbs of payload capability.

• SPS Contingency  $\Delta V$ 

The SPS contingency  $\Delta V$  decreased 2.2 fps/degree of launch azimuth on the average. Over half (56%) of the data showed the highest contingency  $\Delta V$  available at an azimuth other than 72°. One-third showed continually decreasing contingency  $\Delta V$  as azimuth increased. The balance showed a minimum contingency  $\Delta V$  at an intermediate azimuth, 90°. Of the 56% that showed an increase in available contingency  $\Delta V$ , 31% showed the best at 90%, 25% at 80° and none at 96°. Sixty-three percent had less available contingency  $\Delta V$  at a higher azimuth than 72°; the maximum drop 463 fps, the average drop 112 fps.

The statistical analysis of the various azimuth changes is summarized in Table I. These sensitivities and trends should

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\*Reference: Caldwell, S. F., and K. E. Martersteck, "Optimization of Launch Azimuth Range to Adjust Launch Window Duration and Improve Launch Vehicle Performance Margin," Bellcomm Memorandum for File B70 12065, Case 310, December 23, 1970.

hold for launch windows defined by other launch azimuth ranges. An 80° to 100° range should show less extremes as the window duration never exceeds 2-3/4 hours compared to up to 4-1/2 hours for a 72°-96° window. This shorter window means less increase in the TLI energy requirements as less time must be made up on the translunar trajectory in order to maintain landing sun elevations within the limits.

#### Conclusions

The full launch azimuth range should be examined when missions are found to be marginal at the azimuth that opens the window (72° for a 72°-96° window or 80° for an 80°-100° window).

Changes in available SPS contingency  $\Delta V$  can be significant. Launch vehicle capability variations over the azimuth range is dominated by the EOI effects. The difference in performance between the beginning and end of the window will be mainly due to the TLI effects for a launch azimuth range of 80° to 100° or other ranges symmetrical about 90°.

  
R. A. Bass  
S. F. Caldwell

2013-RAB-SFC-slr

Attachments

TABLE I - SUMMARY

	Average	Standard Deviation	Figure #
Change in Available SPS Contingency ΔV as Launch Azimuth Increases from 72° to 80°	0.6 fps	61.3 fps	2
80° to 90°	-27.1	48.7	3
90° to 96°	-23.8	18.9	4
72° to 96°	-50.3	111.4	5
Change in Available SPS Contingency ΔV for One Degree of Launch Azimuth Change	-2.2	4.3	6
Change in Launch Vehicle Capability Due to TLI Energy Requirements as Launch Azimuth Increases from 72° to 80°	-18.4 lbs	25.9 lbs	7
80° to 90°	-29.0	35.2	8
90° to 96°	-22.6	18.2	9
72° to 96°	-70.0	74.2	10
Change in Launch Vehicle Capability Due to TLI Energy Requirements for One Degree of Launch Azimuth Change	-3.0	3.0	11

## $\Delta V$ SYNOPSIS

The  $\Delta V$  synopsis contains the following data for each mission considered.

AZ	- Launch azimuth (deg)
SITE	- Lunar landing site
LAUNCH DATE	- Date of launch
LVCAP	- Launch vehicle capability* (lbs)
WGTINJ	- Injected spacecraft weight with the SPS tanks offloaded to the amount of fuel used (lbs)
CNTGNCY	- Available contingency $\Delta V$ (fps)
LOI	- Lunar orbit insertion $\Delta V$ (fps)
PLCH	- CSM plane change $\Delta V$ (fps)
TEI	- Transearth injection $\Delta V$ (fps)
E	- Minus the translunar injection energy divided by one million ( $ft^2/sec^2$ )

The mission constraints and spacecraft weight model follow the  $\Delta V$  synopsis.

---

\*Launch vehicle capability is computed including effects of wind and temperature, Flight Geometry Reserves available, and mission specific energy. The effect of payload gain due to propellant requirement variation into earth orbit as illustrated in Figure 1 is also included.

## AV SYNOPSIS - PAGE 2

AZ SITE LAUNCH DATE	LVCAP	WTINJ	CNTGNCY	LOI	PLCH	TEL	E
72 MARIUS JUL30, 1971	107970.	103553.	1554.	2723.	11.	2803.	10.147
80 MARIUS JUL30, 1971	108526.	103724.	1520.	2743.	11.	2798.	10.099
90 MARIUS JUL30, 1971	108814.	104009.	1263.	2771.	11.	2800.	10.074
90 MARIUS JUL30, 1971	108766.	103915.	1281.	2755.	11.	2813.	10.099
72 MARIUS AUG29, 1971	107969.	105264.	1013.	2864.	11.	2868.	10.154
80 MARIUS AUG29, 1971	108525.	105080.	1049.	2848.	11.	2867.	10.106
90 MARIUS AUG29, 1971	108793.	105110.	1043.	2849.	11.	2867.	10.007
90 MARIUS AUG29, 1971	108713.	105249.	1016.	2863.	11.	2867.	9.918
72 MARIUS SEP27, 1971	108663.	106908.	685.	2898.	11.	3130.	10.741
80 MARIUS SEP27, 1971	108659.	106732.	719.	2873.	11.	3141.	10.762
90 MARIUS SEP27, 1971	108637.	106702.	725.	2862.	11.	3157.	10.772
90 MARIUS SEP27, 1971	108684.	106814.	703.	2867.	11.	3169.	10.782
72 MARIUS OCT27, 1971	107820.	109343.	218.	2901.	11.	3585.	10.681
80 MARIUS OCT27, 1971	1085371.	109369.	213.	2903.	11.	3580.	10.613
90 MARIUS OCT27, 1971	108633.	109561.	176.	2922.	11.	3585.	10.495
90 MARIUS OCT27, 1971	108657.	109727.	144.	2938.	11.	3585.	10.418
72 MARIUS NOV26, 1971	107236.	115410.	-924.	3345.	10.	3825.	9.192
80 MARIUS NOV26, 1971	107746.	116069.	-1049.	3403.	10.	3825.	8.976
90 MARIUS NOV26, 1971	107961.	116788.	-1185.	3468.	10.	3825.	8.688
90 MARIUS NOV26, 1971	107862.	117065.	-1237.	3493.	10.	3825.	8.531
AVAILABLE CONTINGENCY	AV FOR 72 DEGREE LAUNCH AZIMUTH LESS THAN	-200.					
72 MARIUS DEC25, 1971	107326.	117175.	-1245.	3433.	10.	3958.	9.916
80 MARIUS DEC25, 1971	107875.	118171.	-1432.	3520.	10.	3962.	9.838
90 MARIUS DEC25, 1971	108153.	118906.	-1569.	3581.	10.	3970.	9.791
90 MARIUS DEC25, 1971	108100.	118805.	-1550.	3570.	10.	3974.	9.798
AVAILABLE CONTINGENCY	AV FOR 72 DEGREE LAUNCH AZIMUTH LESS THAN	-200.					
72 MARIUS JAN24, 1972	108606.	122386.	-2212.	3035.	10.	3694.	8.531
80 MARIUS JAN25, 1972	107378.	123833.	-2484.	3958.	10.	3694.	8.255
90 MARIUS JAN25, 1972	107618.	124708.	-2649.	4033.	10.	3695.	8.057
90 MARIUS JAN25, 1972	107481.	125018.	-2708.	4058.	10.	3694.	7.761
AVAILABLE CONTINGENCY	AV FOR 72 DEGREE LAUNCH AZIMUTH LESS THAN	-200.					
72 MARIUS FEB22, 1972	107034.	119370.	-1682.	3730.	10.	3579.	9.158
80 MARIUS FEB22, 1972	107593.	120179.	-1835.	3800.	10.	3581.	9.119
90 MARIUS FEB23, 1972	107865.	120558.	-1907.	3831.	10.	3585.	9.109
90 MARIUS FEB23, 1972	107830.	120404.	-1877.	3816.	10.	3588.	9.109
AVAILABLE CONTINGENCY	AV FOR 72 DEGREE LAUNCH AZIMUTH LESS THAN	-200.					

## AV SYNOPSIS - PAGE 3

AZ SITE LAUNCH DATE	LVCAP	WTGTRN	CONTING	L01	PLCH	TEI	E
72 MARIUS MAR20,1972	106769.	114880.	-871.	3018.	16.	3198.	8.027
80 MARIUS MAR20,1972	107313.	115492.	-991.	3074.	16.	3198.	7.860
90 MARIUS MAR20,1972	107542.	115888.	-1069.	3710.	16.	3198.	7.622
90 MARIUS MAR20,1972	107447.	115888.	-1069.	3710.	16.	3198.	7.477
AVAILABLE CONTINGENCY AV FOR 72 DEGREE LAUNCH AZIMUTH LESS THAN -200.							
72 MARIUS APR21,1972	107244.	109798.	117.	3247.	16.	2988.	9.100
80 MARIUS APR21,1972	107809.	110325.	13.	3294.	16.	2995.	9.081
90 MARIUS APR21,1972	108104.	110598.	-40.	3312.	16.	3011.	9.081
90 MARIUS APR21,1972	108038.	110540.	-29.	3304.	16.	3016.	9.042
72 MARIUS MAY21,1972	107164.	106791.	710.	3097.	16.	2701.	7.965
80 MARIUS MAY21,1972	107707.	107303.	608.	3148.	16.	2700.	7.867
90 MARIUS MAY21,1972	107952.	107700.	529.	3187.	16.	2700.	7.688
90 MARIUS MAY21,1972	107857.	107771.	514.	3194.	16.	2700.	7.542
72 MARIUS JUN19,1972	107689.	103945.	1276.	2764.	16.	2790.	9.326
80 MARIUS JUN19,1972	108251.	104437.	1178.	2814.	16.	2790.	9.297
90 MARIUS JUN19,1972	108543.	104773.	1111.	2843.	16.	2800.	9.287
90 MARIUS JUN19,1972	108469.	104783.	1109.	2844.	16.	2800.	9.219
72 MARIUS JUL19,1972	107489.	104874.	1093.	2888.	11.	2741.	8.437
80 MARIUS JUL19,1972	108051.	105102.	1036.	2917.	11.	2741.	8.408
90 MARIUS JUL19,1972	108313.	105550.	958.	2956.	11.	2741.	8.289
90 MARIUS JUL19,1972	108217.	105700.	928.	2971.	11.	2741.	8.142
72 MARIUS AUG17,1972	107909.	104467.	1168.	2747.	11.	2941.	9.933
80 MARIUS AUG17,1972	108471.	104289.	1203.	2729.	11.	2941.	9.904
90 MARIUS AUG17,1972	108749.	104304.	1201.	2730.	11.	2942.	9.845
90 MARIUS AUG17,1972	108675.	104417.	1178.	2742.	11.	2941.	9.776
72 MARIUS SEP16,1972	107684.	107542.	561.	2954.	10.	3140.	9.276
80 MARIUS SEP16,1972	108232.	107629.	544.	2962.	10.	3141.	9.197
90 MARIUS SEP16,1972	108483.	107904.	490.	2989.	10.	3141.	9.038
90 MARIUS SEP16,1972	108396.	108124.	448.	3011.	10.	3140.	8.921
72 DESLAR JUL25,1971	107294.	104991.	1068.	2869.	35.	2779.	7.726
80 DESLAR JUL25,1971	107831.	105095.	1047.	2879.	35.	2780.	7.608
90 DESLAR JUL25,1971	108066.	105373.	992.	2907.	35.	2780.	7.390
90 DESLAR JUL25,1971	107968.	105593.	948.	2929.	35.	2780.	7.235

## AV SYNOPSIS - PAGE 4

AZ	SITE	LAUNCH DATE	LVCAP	WTINJ	CNTNCY	LOI	PLCH	TEI	E
72	DESLAR	AUG23,1971	107734.	103929.	1275.	2096.	35.	2910.	9.306
80	DESLAR	AUG23,1971	108293.	103870.	1286.	2090.	35.	2910.	9.268
90	DESLAR	AUG23,1971	108563.	103969.	1267.	2100.	35.	2910.	9.179
90	DESLAR	AUG23,1971	108487.	104106.	1240.	2114.	35.	2910.	9.102
72	DESLAR	SEP22,1971	107405.	106373.	791.	2092.	224.	2821.	8.328
80	DESLAR	SEP22,1971	107967.	106182.	829.	2073.	224.	2821.	8.249
90	DESLAR	SEP22,1971	108226.	106273.	811.	2082.	224.	2821.	8.170
90	DESLAR	SEP22,1971	108128.	106534.	758.	2008.	224.	2821.	8.014
72	DESLAR	OCT21,1971	107642.	104898.	1081.	2750.	332.	2726.	9.865
80	DESLAR	OCT21,1971	108212.	104660.	1128.	2713.	332.	2726.	9.866
90	DESLAR	OCT21,1971	108507.	104601.	1139.	2704.	332.	2734.	9.865
90	DESLAR	OCT21,1971	108436.	104735.	1113.	2717.	332.	2735.	9.807
72	DESLAR	NOV20,1971	107321.	106671.	732.	2933.	359.	2664.	9.387
80	DESLAR	NOV20,1971	107872.	106525.	760.	2919.	359.	2663.	9.319
90	DESLAR	NOV20,1971	108128.	106606.	745.	2927.	359.	2663.	9.180
90	DESLAR	NOV20,1971	108044.	106792.	708.	2945.	359.	2664.	9.073
72	DESLAR	DEC19,1971	107491.	106050.	855.	2858.	305.	2744.	10.435
80	DESLAR	DEC19,1971	108055.	105920.	880.	2842.	305.	2750.	10.416
90	DESLAR	DEC19,1971	108348.	105905.	883.	2834.	305.	2763.	10.406
90	DESLAR	DEC19,1971	108295.	105976.	869.	2035.	305.	2715.	10.416
72	DESLAR	JAN10,1972	107387.	105099.	1047.	2885.	88.	2716.	10.301
80	DESLAR	JAN10,1972	107935.	104985.	1070.	2873.	88.	2717.	10.223
90	DESLAR	JAN10,1972	108194.	105034.	1060.	2878.	88.	2717.	10.095
90	DESLAR	JAN10,1972	108118.	105158.	1035.	2891.	88.	2716.	10.017
72	DESLAR	FEB17,1972	108993.	104720.	1126.	2926.	6.	2630.	8.998
80	DESLAR	FEB17,1972	107501.	104879.	1095.	2942.	6.	2630.	8.773
90	DESLAR	FEB17,1972	107713.	105186.	1033.	2973.	6.	2630.	8.474
90	DESLAR	FEB17,1972	107618.	105376.	995.	2992.	6.	2630.	8.350
72	DESLAR	MAR17,1972	107287.	104095.	1246.	2773.	102.	2723.	9.892
80	DESLAR	MAR17,1972	107649.	104499.	1165.	2804.	102.	2743.	9.863
90	DESLAR	MAR17,1972	108139.	104944.	1076.	2835.	102.	2771.	9.843
90	DESLAR	MAR17,1972	108084.	104899.	1085.	2825.	102.	2782.	9.844

## AV SYNOPSIS - PAGE 5

AV SITE	LAUNCH DATE	LCVAP	WTINW	CNTNCY	L01	PLCH	TEI	E
72 DESCAR	APR16,1972	107074.	104506.	1166.	2053.	102.	2640.	8.599
80 DESCAR	APR16,1972	107581.	104862.	1095.	2089.	102.	2640.	8.373
90 DESCAR	APR16,1972	107793.	105209.	1026.	2924.	102.	2640.	8.075
90 DESCAR	APR16,1972	107701.	105279.	1012.	2931.	102.	2640.	7.958
72 DESCAR	MAY15,1972	107488.	103679.	1330.	2749.	75.	2713.	9.310
80 DESCAR	MAY15,1972	108058.	103953.	1275.	2769.	75.	2729.	9.310
90 DESCAR	MAY15,1972	108353.	104135.	1238.	2777.	75.	2750.	9.310
90 DESCAR	MAY15,1972	108296.	104130.	1239.	2771.	75.	2761.	9.301
72 DESCAR	JUN14,1972	107254.	103955.	1279.	2044.	6.	2647.	7.817
80 DESCAR	JUN14,1972	107778.	104113.	1248.	2060.	6.	2647.	7.050
90 DESCAR	JUN14,1972	108601.	104408.	1188.	2090.	6.	2647.	7.392
90 DESCAR	JUN14,1972	107900.	104631.	1144.	2912.	6.	2640.	7.227
72 DESCAR	JUL15,1972	107438.	103089.	1449.	2097.	34.	2737.	8.980
80 DESCAR	JUL15,1972	108214.	103021.	1462.	2080.	34.	2745.	9.001
90 DESCAR	JUL15,1972	108401.	103138.	1439.	2097.	34.	2747.	8.902
90 DESCAR	JUL15,1972	108402.	103264.	1413.	2710.	34.	2747.	8.814
72 DESCAR	AUG12,1972	107159.	106299.	807.	2931.	250.	2703.	7.235
80 DESCAR	AUG12,1972	107897.	106319.	803.	2933.	250.	2703.	7.118
90 DESCAR	AUG12,1972	107926.	106581.	750.	2959.	250.	2703.	6.879
90 DESCAR	AUG12,1972	107619.	106354.	897.	2980.	250.	2703.	6.095
72 DESCAR	SEP10,1972	107608.	104451.	1170.	2727.	277.	2713.	8.944
80 DESCAR	SEP10,1972	108167.	104333.	1194.	2715.	277.	2713.	8.905
90 DESCAR	SEP10,1972	108435.	104412.	1178.	2723.	277.	2713.	8.806
90 DESCAR	SEP10,1972	108353.	104570.	1147.	2739.	277.	2713.	8.709
72 HADLEY	JUL26,1971	107552.	105017.	1064.	2083.	7.	2784.	7.932
80 HADLEY	JUL26,1971	107895.	104987.	1069.	2080.	7.	2784.	7.834
90 HADLEY	JUL26,1971	108135.	105171.	1033.	2098.	7.	2785.	7.636
90 HADLEY	JUL26,1971	108039.	105335.	1000.	2915.	7.	2784.	7.489
72 HADLEY	AUG24,1971	107578.	106097.	846.	2095.	118.	2860.	8.748
80 HADLEY	AUG24,1971	108148.	105722.	920.	2058.	118.	2865.	8.748
90 HADLEY	AUG24,1971	108457.	105547.	955.	2343.	118.	2860.	8.799
90 HADLEY	AUG24,1971	108368.	105626.	939.	2052.	118.	2858.	8.748

## AV SYNOPSIS - PAGE 6

AZ	SITE	LAUNCH DATE	EVCA#	WTG INJ	CNTGNCY	L01	PLCH	TE1	E
72	HADLEY	SEP23, 1971	107400.	108308.	411.	3046.	168.	2949.	8.320
80	HADLEY	SEP23, 1971	107979.	107776.	515.	2993.	168.	2951.	8.351
90	HADLEY	SEP23, 1971	108516.	107527.	564.	2962.	168.	2964.	8.502
90	HADLEY	SEP23, 1971	108241.	107726.	525.	2979.	168.	2969.	8.432
72	HADLEY	OCT22, 1971	107576.	111212.	-129.	2944.	515.	3344.	9.657
80	HADLEY	OCT22, 1971	108138.	110681.	-30.	2893.	515.	3345.	9.628
90	HADLEY	OCT22, 1971	108408.	110377.	28.	2864.	515.	3345.	9.559
90	HADLEY	OCT22, 1971	108327.	110446.	15.	2870.	516.	3345.	9.446
72	HADLEY	NOV21, 1971	107117.	112140.	-322.	3213.	218.	3291.	8.674
80	HADLEY	NOV21, 1971	107556.	111769.	-250.	3178.	218.	3291.	8.561
90	HADLEY	NOV21, 1971	107899.	111584.	-215.	3161.	218.	3290.	8.373
90	HADLEY	NOV21, 1971	107843.	111625.	-223.	3167.	218.	3280.	8.369
AVAILABLE CONTINGENCY AV FOR 72 DEGREE LAUNCH AZIMUTH LESS THAN -200.									
72	HADLEY	DEC21, 1971	108966.	111811.	-263.	3234.	18.	3389.	8.571
80	HADLEY	DEC21, 1971	107488.	111526.	-208.	3207.	18.	3389.	8.399
90	HADLEY	DEC21, 1971	107707.	111441.	-191.	3199.	18.	3389.	8.126
90	HADLEY	DEC21, 1971	107604.	111547.	-212.	3209.	18.	3389.	7.952
AVAILABLE CONTINGENCY AV FOR 72 DEGREE LAUNCH AZIMUTH LESS THAN -200.									
72	HADLEY	JAN19, 1972	107147.	110185.	54.	3047.	17.	3453.	9.443
80	HADLEY	JAN19, 1972	107720.	109826.	123.	3012.	17.	3454.	9.454
90	HADLEY	JAN19, 1972	108017.	109618.	163.	2990.	17.	3455.	9.463
90	HADLEY	JAN19, 1972	107959.	109650.	157.	2992.	17.	3460.	9.453
72	HADLEY	FEB16, 1972	108697.	109011.	279.	2925.	158.	3330.	8.653
80	HADLEY	FEB16, 1972	107390.	109472.	191.	2969.	158.	3331.	8.377
90	HADLEY	FEB16, 1972	107588.	110195.	52.	3039.	158.	3330.	8.029
90	HADLEY	FEB16, 1972	107491.	110456.	2.	3064.	158.	3330.	7.875
72	HADLEY	MAR16, 1972	107062.	108357.	406.	2831.	407.	3141.	9.070
80	HADLEY	MAR16, 1972	107577.	108255.	426.	2823.	407.	3137.	8.873
90	HADLEY	MAR16, 1972	107631.	108302.	416.	2836.	407.	3121.	8.724
90	HADLEY	MAR16, 1972	107791.	108120.	451.	2828.	407.	3102.	8.777
72	HADLEY	APR17, 1972	106927.	108001.	472.	2909.	258.	3070.	8.048
80	HADLEY	APR17, 1972	107431.	108658.	345.	2973.	258.	3070.	7.812
90	HADLEY	APR17, 1972	107638.	109391.	203.	3044.	258.	3070.	7.495
90	HADLEY	APR17, 1972	107539.	109629.	157.	3067.	258.	3070.	7.337

## AV SYNOPSIS - PAGE 7

AC	SITE	LAUNCH DATE	LVCAP	WTINJ	CNTNCY	L01	PLCH	TE1	C
72	HADLEY	MAY16,1972	107374.	104658.	1129.	2730.	158.	2867.	8.869
80	HADLEY	MAY16,1972	107328.	104771.	1107.	2744.	158.	2862.	8.811
90	HADLEY	MAY16,1972	108217.	104791.	1103.	2749.	158.	2850.	8.790
90	HADLEY	MAY16,1972	108165.	104722.	1117.	2744.	158.	2852.	8.800
72	HADLEY	JUN15,1972	107176.	105057.	1060.	2690.	8.	2773.	7.523
80	HADLEY	JUN15,1972	107699.	105430.	982.	2929.	8.	2774.	7.356
90	HADLEY	JUN15,1972	107323.	105914.	885.	2978.	8.	2773.	7.098
90	HADLEY	JUN15,1972	107819.	106155.	837.	3002.	8.	2773.	6.924
72	HADLEY	JUL14,1972	107567.	103731.	1021.	2778.	17.	2723.	8.724
80	HADLEY	JUL14,1972	108143.	103530.	1061.	2750.	17.	2720.	8.745
90	HADLEY	JUL14,1972	108449.	103490.	1068.	2748.	17.	2734.	8.785
90	HADLEY	JUL14,1972	108388.	103564.	1054.	2754.	17.	2737.	8.765
72	HADLEY	AUG15,1972	107241.	105539.	960.	2944.	17.	2757.	7.528
80	HADLEY	AUG15,1972	107789.	105340.	1000.	2924.	17.	2757.	7.450
90	HADLEY	AUG15,1972	108029.	105405.	987.	2931.	17.	2750.	7.251
90	HADLEY	AUG15,1972	107925.	105584.	951.	2949.	17.	2750.	7.076
72	HADLEY	SEP11,1972	107420.	107056.	657.	2970.	117.	2907.	8.277
80	HADLEY	SEP11,1972	107580.	106551.	755.	2920.	117.	2907.	8.243
90	HADLEY	SEP11,1972	108284.	106279.	810.	2897.	117.	2899.	8.275
90	HADLEY	SEP11,1972	108192.	106380.	790.	2907.	117.	2899.	8.139
72	COPERN.	JUL27,1971	107638.	103257.	1417.	2730.	8.	2731.	9.677
80	COPERN.	JUL27,1971	108406.	102959.	1476.	2690.	8.	2734.	9.673
90	COPERN.	JUL27,1971	108704.	102906.	1486.	2686.	8.	2747.	9.683
90	COPERN.	JUL27,1971	108649.	103017.	1463.	2693.	8.	2750.	9.683
72	COPERN.	AUG26,1971	107798.	105080.	1047.	2602.	251.	2710.	9.538
80	COPERN.	AUG26,1971	108365.	104713.	1119.	2765.	251.	2710.	9.529
90	COPERN.	AUG26,1971	108644.	104639.	1134.	2757.	251.	2717.	9.469
90	COPERN.	AUG26,1971	108559.	104822.	1098.	2776.	251.	2710.	9.362
72	COPERN.	SEP24,1971	107903.	106638.	737.	2622.	412.	2824.	10.136
80	COPERN.	SEP24,1971	108478.	106211.	821.	2777.	412.	2829.	10.157
90	COPERN.	SEP24,1971	108779.	106051.	852.	2750.	412.	2839.	10.177
90	COPERN.	SEP24,1971	108727.	106232.	817.	2769.	412.	2849.	10.187

## AV SYNOPSIS - PAGE 8

AZ	SITE	LAUNCH DATE	LVCAP	WG1INJ	CNTNCY	L01	PLCH	TEI	E
72	CUPERN	OCT24, 1971	107605.	108597.	355.	3036.	304.	2889.	9.821
80	CUPERN	OCT24, 1971	108184.	108321.	410.	3006.	304.	2895.	9.852
90	CUPERN	OCT24, 1971	108494.	108234.	426.	2992.	304.	2906.	9.923
90	CUPERN	OCT24, 1971	108432.	108312.	411.	2998.	304.	2909.	9.882
72	CUPERN	NOV20, 1971	107282.	109267.	222.	3164.	7.	3060.	9.304
80	CUPERN	NOV20, 1971	107817.	109050.	265.	3143.	7.	3060.	9.177
90	CUPERN	NOV20, 1971	108054.	109009.	273.	3139.	7.	3060.	8.968
90	CUPERN	NOV20, 1971	107961.	109122.	251.	3150.	7.	3060.	8.831
72	CUPERN	DEC22, 1971	107467.	108263.	422.	2961.	7.	3268.	10.384
80	CUPERN	DEC22, 1971	108062.	107936.	484.	2927.	7.	3272.	10.475
90	CUPERN	DEC22, 1971	108360.	107747.	521.	2906.	7.	3277.	10.485
90	CUPERN	DEC22, 1971	108294.	107768.	517.	2906.	7.	3277.	10.445
72	CUPERN	JAN21, 1972	107141.	108033.	466.	2880.	101.	3289.	9.434
80	CUPERN	JAN21, 1972	107600.	108433.	390.	2919.	101.	3289.	9.248
90	CUPERN	JAN21, 1972	107688.	108968.	286.	2971.	101.	3289.	9.009
90	CUPERN	JAN21, 1972	107600.	109143.	252.	2988.	101.	3289.	8.891
72	CUPERN	FEB20, 1972	108354.	111054.	-118.	3189.	478.	2879.	8.704
80	CUPERN	FEB20, 1972	108792.	112101.	-321.	3288.	478.	2879.	8.230
90	CUPERN	FEB20, 1972	108922.	113212.	-537.	3392.	478.	2879.	5.653
90	CUPERN	FEB21, 1972	108802.	113438.	-581.	3413.	478.	2879.	5.402
72	CUPERN	MAR20, 1972	107028.	106388.	787.	2815.	425.	2770.	8.921
80	CUPERN	MAR20, 1972	107551.	106943.	678.	2870.	425.	2770.	8.754
90	CUPERN	MAR20, 1972	107783.	107491.	571.	2924.	425.	2776.	8.526
90	CUPERN	MAR20, 1972	107695.	107608.	549.	2936.	425.	2775.	8.408
72	CUPERN	APR18, 1972	107262.	104845.	1091.	2728.	290.	2777.	9.232
80	CUPERN	APR18, 1972	107824.	105143.	1032.	2753.	290.	2787.	9.203
90	CUPERN	APR18, 1972	108116.	105343.	993.	2763.	290.	2807.	9.193
90	CUPERN	APR18, 1972	108061.	105339.	993.	2756.	290.	2820.	9.193
72	CUPERN	MAY18, 1972	107278.	105761.	1316.	2797.	20.	2680.	8.466
80	CUPERN	MAY18, 1972	107816.	104095.	1249.	2831.	20.	2680.	8.348
90	CUPERN	MAY18, 1972	108061.	104410.	1186.	2863.	20.	2680.	8.170
90	CUPERN	MAY18, 1972	107974.	104509.	1167.	2873.	20.	2680.	8.053

## AV SYNOPSIS - PAGE 9

AZ	SITE	LAUNCH DATE	LVCAP	WTINJ	CNFGNCY	LOI	PLCH	TEI	E
72	COPERN	JUN16,1972	107648.	102566.	1554.	2051.	7.	2748.	9.211
80	COPERN	JUN16,1972	108215.	102600.	1547.	2050.	7.	2757.	9.202
90	COPERN	JUN16,1972	108510.	102696.	1527.	2051.	7.	2775.	9.202
90	COPERN	JUN16,1972	108455.	102754.	1514.	2050.	7.	2789.	9.202
72	COPERN	JUL16,1972	107476.	103735.	1323.	2023.	7.	2643.	8.394
80	COPERN	JUL16,1972	108027.	103554.	1359.	2005.	7.	2642.	8.326
90	COPERN	JUL16,1972	108284.	103617.	1347.	2011.	7.	2640.	8.187
90	COPERN	JUL16,1972	108193.	103784.	1313.	2028.	7.	2643.	8.060
72	COPERN	AUG14,1972	107793.	104576.	1145.	2716.	277.	2760.	9.515
80	COPERN	AUG14,1972	108358.	104211.	1216.	2079.	277.	2760.	9.496
90	COPERN	AUG14,1972	108650.	104123.	1233.	2066.	277.	2760.	9.486
90	COPERN	AUG14,1972	108595.	104247.	1209.	2073.	277.	2779.	9.486
72	COPERN	SEP13,1972	107565.	106341.	798.	2911.	250.	2751.	8.818
80	COPERN	SEP13,1972	108124.	105994.	860.	2076.	250.	2752.	8.779
90	COPERN	SEP13,1972	108386.	105924.	880.	2069.	250.	2752.	8.660
90	COPERN	SEP13,1972	108298.	106095.	846.	2086.	250.	2752.	8.542
72	DAVY	JUL26,1971	107705.	105282.	1003.	2705.	216.	2983.	9.202
80	DAVY	JUL26,1971	108286.	105152.	1028.	2093.	216.	2981.	9.243
90	DAVY	JUL26,1971	108590.	105102.	1038.	2089.	216.	2979.	9.273
90	DAVY	JUL26,1971	108532.	105127.	1033.	2092.	216.	2978.	9.264
72	DAVY	AUG25,1971	107602.	107429.	584.	2822.	404.	2985.	8.853
80	DAVY	AUG25,1971	108164.	107297.	609.	2809.	404.	2985.	8.804
90	DAVY	AUG25,1971	108426.	107419.	586.	2821.	404.	2985.	8.685
90	DAVY	AUG25,1971	108335.	107643.	542.	2843.	404.	2985.	8.558
72	DAVY	SEP23,1971	107791.	106282.	806.	2747.	457.	2857.	9.726
80	DAVY	SEP23,1971	108367.	106006.	660.	2720.	457.	2856.	9.748
90	DAVY	SEP23,1971	108670.	105900.	680.	2710.	457.	2855.	9.777
90	DAVY	SEP23,1971	108615.	105951.	671.	2715.	457.	2855.	9.777
72	DAVY	OCT23,1971	107549.	107405.	586.	2890.	563.	2689.	9.590
80	DAVY	OCT23,1971	108106.	107263.	616.	2870.	563.	2689.	9.541
90	DAVY	OCT23,1971	108367.	107344.	600.	2884.	563.	2689.	9.422
90	DAVY	OCT23,1971	108285.	107538.	562.	2903.	563.	2689.	9.325

## AV SYNOPSIS - PAGE 10

AZ	SITE	LAUNCH DATE	LVCAP	WTINJ	CNTNCY	LOT	PLCH	TEI	E
72	DAVY	NOV21,1971	107586.	100919.	683.	2049.	510.	2720.	10.357
80	DAVY	NOV21,1971	108150.	100798.	706.	2035.	510.	2732.	10.358
90	DAVY	NOV21,1971	108445.	100773.	711.	2027.	510.	2740.	10.358
90	DAVY	NOV21,1971	108393.	100855.	695.	2030.	510.	2750.	10.348
72	DAVY	DEC21,1971	107455.	100350.	796.	2095.	522.	2713.	10.352
80	DAVY	DEC21,1971	108004.	100280.	610.	2088.	522.	2710.	10.255
90	DAVY	DEC21,1971	108268.	100345.	797.	2094.	522.	2714.	10.145
90	DAVY	DEC21,1971	108192.	100486.	769.	2008.	522.	2714.	10.068
72	DAVY	JAN20,1972	107058.	105734.	922.	2989.	80.	2643.	9.130
80	DAVY	JAN20,1972	107574.	105734.	922.	2989.	80.	2643.	8.934
90	DAVY	JAN20,1972	107794.	105944.	680.	3010.	80.	2643.	8.660
90	DAVY	JAN20,1972	107701.	106165.	636.	3032.	80.	2643.	8.529
72	DAVY	FEB18,1972	107245.	103418.	1384.	2751.	1.	2729.	9.899
80	DAVY	FEB18,1972	107611.	103427.	1381.	2743.	1.	2747.	9.890
90	DAVY	FEB18,1972	108103.	103603.	1345.	2740.	1.	2773.	9.880
90	DAVY	FEB18,1972	108045.	103627.	1340.	2746.	1.	2782.	9.870
72	DAVY	MAR19,1972	107006.	103645.	1340.	2800.	1.	2677.	8.857
80	DAVY	MAR19,1972	107519.	103930.	1283.	2829.	1.	2677.	8.051
90	DAVY	MAR19,1972	107737.	104254.	1219.	2862.	1.	2677.	8.373
90	DAVY	MAR19,1972	107649.	104333.	1203.	2870.	1.	2677.	8.255
72	DAVY	APR17,1972	107260.	103236.	1420.	2718.	20.	2730.	9.246
80	DAVY	APR17,1972	107630.	103431.	1379.	2730.	20.	2749.	9.248
90	DAVY	APR17,1972	108128.	103596.	1346.	2735.	20.	2773.	9.257
90	DAVY	APR17,1972	108070.	103606.	1343.	2731.	20.	2780.	9.246
72	DAVY	MAY17,1972	107236.	104191.	1229.	2811.	53.	2715.	8.345
80	DAVY	MAY17,1972	107766.	104269.	1213.	2819.	53.	2715.	8.198
90	DAVY	MAY17,1972	108003.	104536.	1160.	2846.	53.	2715.	7.990
90	DAVY	MAY17,1972	107910.	104773.	1113.	2870.	53.	2715.	7.854
72	DAVY	JUN15,1972	107525.	104280.	1205.	2724.	215.	2740.	8.781
80	DAVY	JUN15,1972	108107.	104152.	1230.	2707.	215.	2754.	8.822
90	DAVY	JUN15,1972	108404.	104172.	1226.	2703.	215.	2760.	8.832
90	DAVY	JUN15,1972	108347.	104231.	1214.	2700.	215.	2772.	8.822

## ΔV SYNOPSIS - PAGE 11

AZ	SITE	LAUNCH DATE	LVCAP	WTINJ	CONTGNCY	LOI	PLCH	TEI	E
72	DAVY	JUL15,1972	107341.	106867.	693.	2861.	429.	2775.	7.908
80	DAVY	JUL15,1972	107683.	106857.	695.	2860.	429.	2775.	7.810
90	DAVY	JUL15,1972	106126.	107080.	652.	2882.	429.	2775.	7.622
90	DAVY	JUL15,1972	106628.	107364.	596.	2910.	429.	2775.	7.466
72	DAVY	AUG010,1972	107668.	105655.	929.	2711.	456.	2800.	9.066
80	DAVY	AUG010,1972	106250.	105441.	971.	2689.	456.	2807.	9.107
90	DAVY	AUG010,1972	106553.	105376.	983.	2681.	456.	2810.	9.137
90	DAVY	AUG010,1972	108481.	105476.	964.	2691.	456.	2810.	9.077
72	DAVY	SEP12,1972	107350.	107869.	497.	2937.	536.	2713.	8.054
80	DAVY	SEP12,1972	107909.	107624.	545.	2913.	536.	2713.	7.995
90	DAVY	SEP12,1972	106162.	107696.	531.	2920.	536.	2713.	7.846
90	DAVY	SEP12,1972	106601.	108012.	469.	2951.	536.	2713.	7.679

## "J" MISSION DESIGN CONSTRAINTS

### Mission Design Constraints

- Only Pacific translunar injections are considered.
- Earth orbit radius = 90 NM.
- $40 \text{ hr.} \leq \text{translunar flight time} \leq 110 \text{ hr.}$
- $40 \text{ NM} \leq \text{perilune altitude of incoming hyperbola} \leq 60 \text{ NM.}$
- A relaxed free return translunar trajectory is used.
- A DPS abort is possible eight hours after perilune.
- A 60 NM lunar parking orbit is employed.
- The time in orbit from lunar orbit insertion to SPS descent orbit insertion (DOI) is approximately 26 hours.
- The CSM takes the LM down to an altitude of 50,000 ft. at which point the LM begins its descent.
- $8^\circ \text{ to } 12^\circ$  Sun elevation at landing.
- The lunar surface stay time is 66 hours.
- The time in lunar orbit from CSM-LM rendezvous to transearth injection is approximately 82 hours.
- $45 \text{ hr.} \leq \text{transearth flight time} \leq 120 \text{ hr.}$
- The return geographic inclination relative to the earth's equator is less than 40 degrees.
- $-35^\circ \leq \text{earth landing latitude} \leq 35^\circ.$
- $-170^\circ \leq \text{earth landing longitude} \leq -150^\circ$  (Pacific zone).
- The maximum mission duration is 14.5 days.

MISSION INDEPENDENT ΔV'S AND WEIGHT MODEL

<u>Event</u>	<u>ΔV (fps)</u>	<u>Weight drop (lbs)</u>
Launch	0.	184.5
Hybrid maneuver	0.	0.
Mid-course correction	0.	340.8
LOI	80.**	69.4
DOI	75.	672.1
CSM circularization	75.	389.7
CSM plane change	0.	92.
LM rescue	600.	0.
Rendezvous	0.	247.3
Bootstrap maneuver	0.	0.
TEI	90.**	179.4
Weather avoidance burn	0.	105.8

SPS Fuel Usable = 39,552	SPS ISP = 314.6
CSM Inert = 27,392	LM ISP = 303.25
SLA = 4,100	
LM = <u>36,300</u>	
Injected Weight = 107,344	

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\*\*Conic Calibration

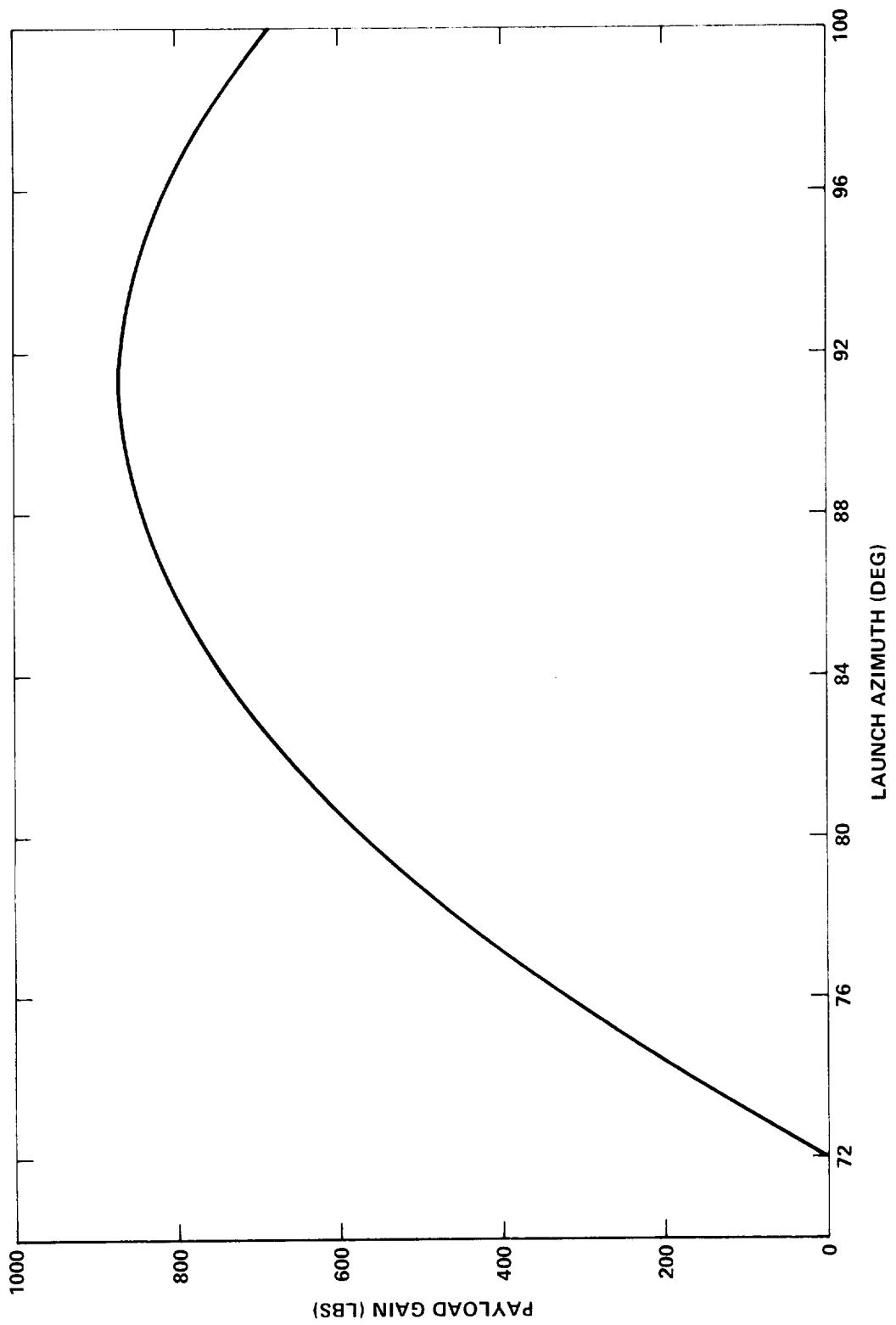


FIGURE 1 - LAUNCH VEHICLE PAYLOAD GAIN DUE TO EARTH ORBIT INSERTION EFFECTS  
FOR VARIOUS LAUNCH AZIMUTHS

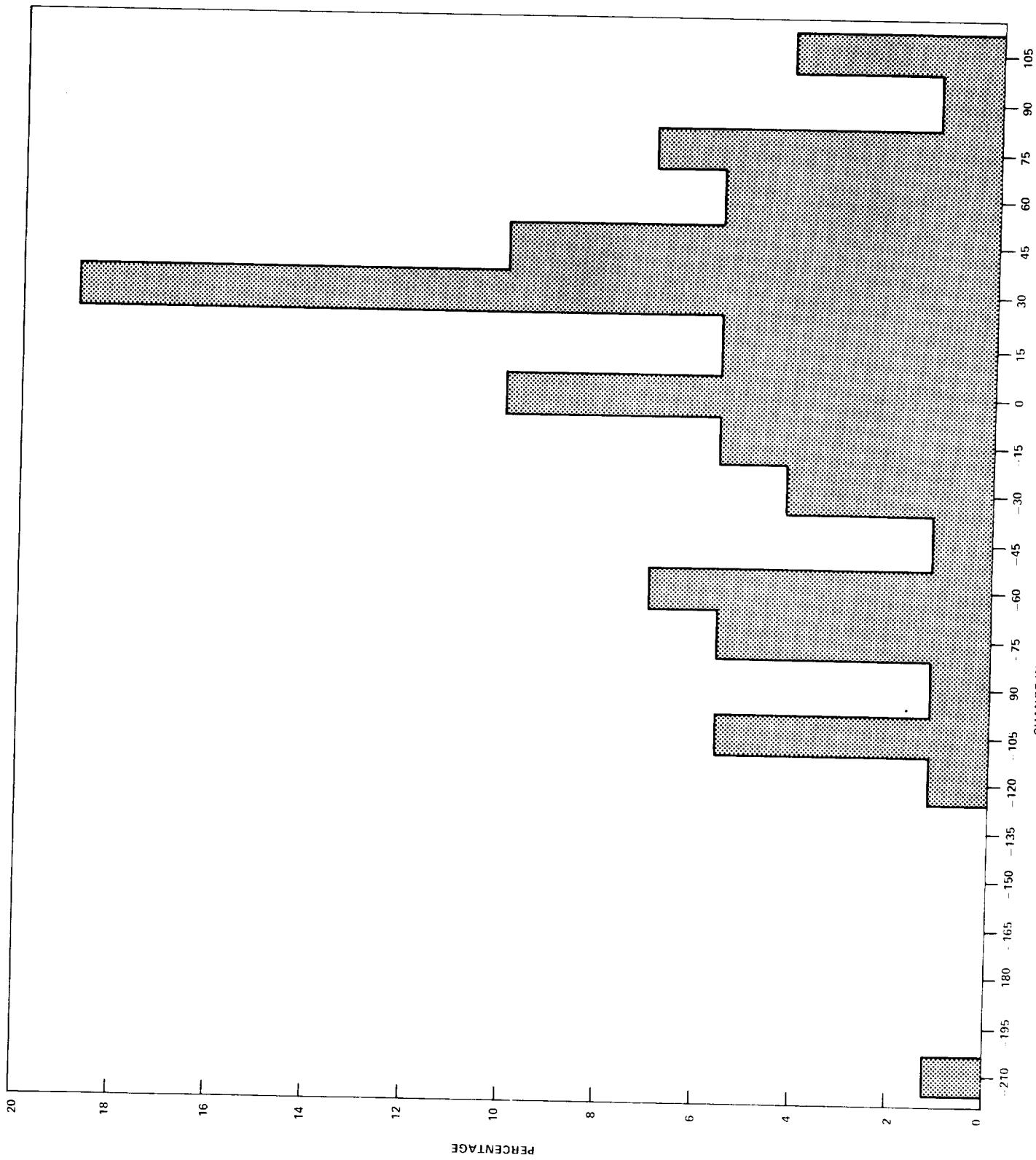


FIGURE 2 FREQUENCY DISTRIBUTION OF CHANGE IN AVAILABLE SPS CONTINGENCY  $\Delta V$  AS LAUNCH AZIMUTH INCREASES FROM 72 TO 80 DEGREES

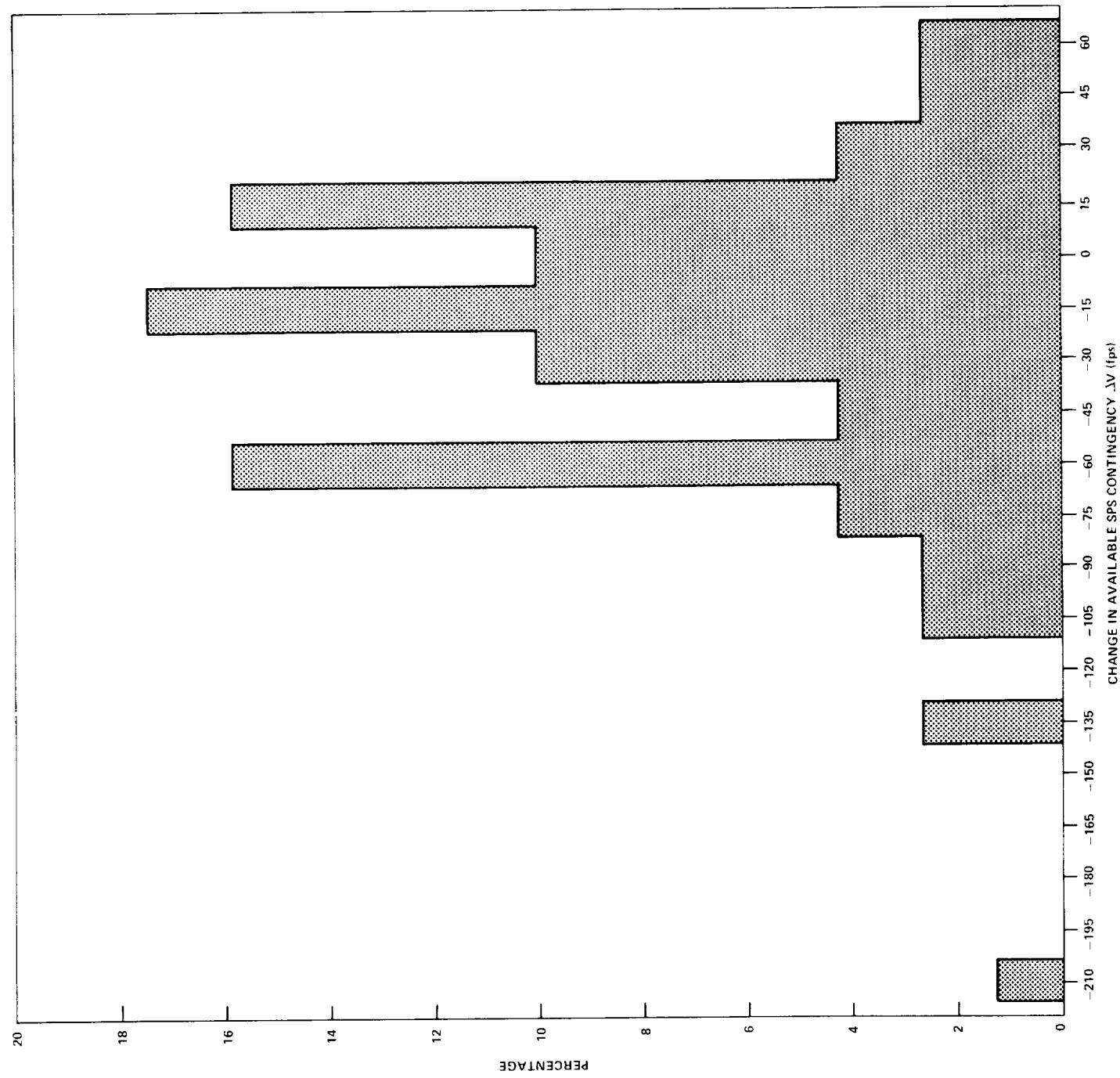


FIGURE 3 : FREQUENCY DISTRIBUTION OF CHANGE IN AVAILABLE SPS CONTINGENCY  $\Delta V$  AS LAUNCH AZIMUTH INCREASES FROM 80 TO 90 DEGREES

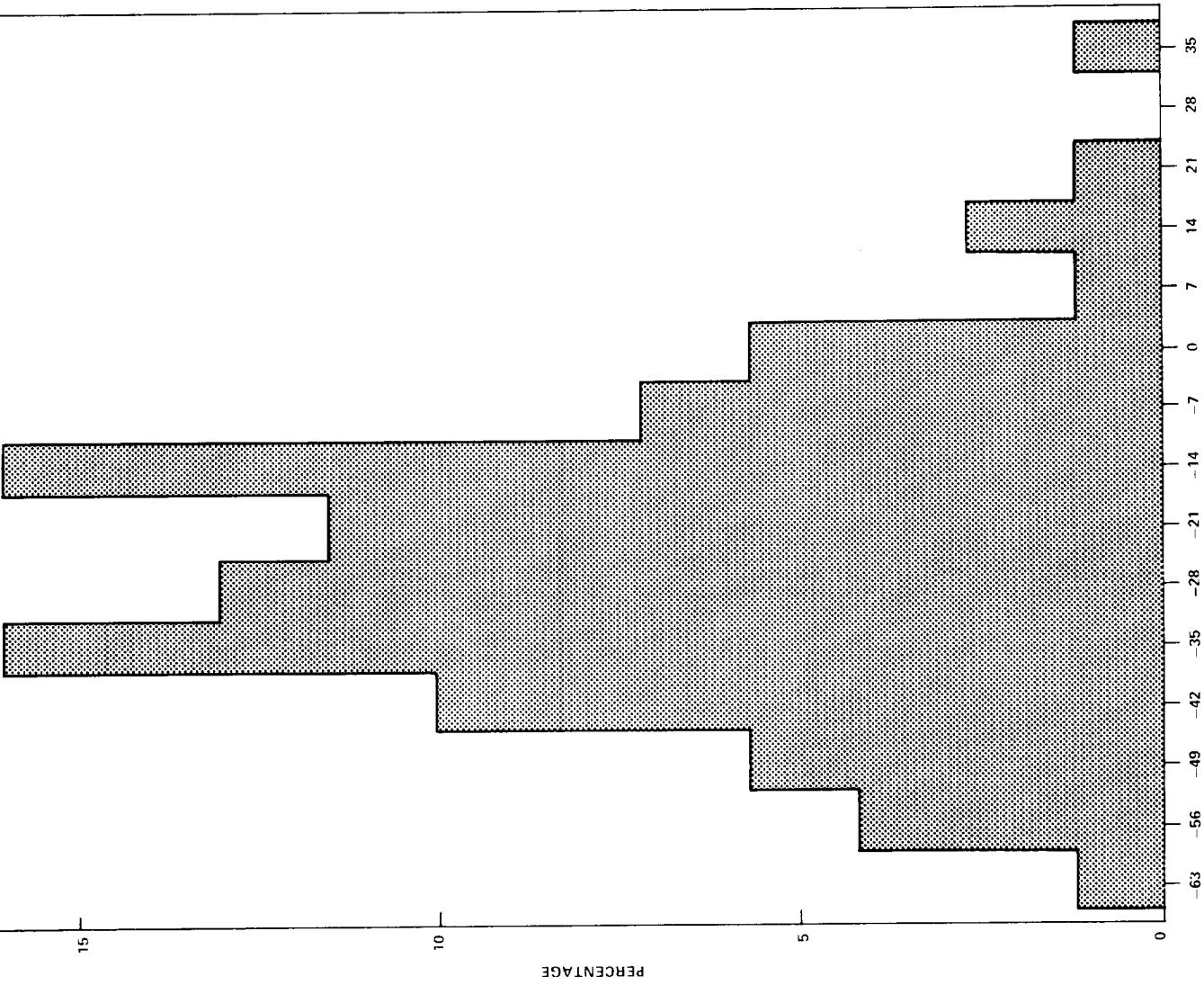
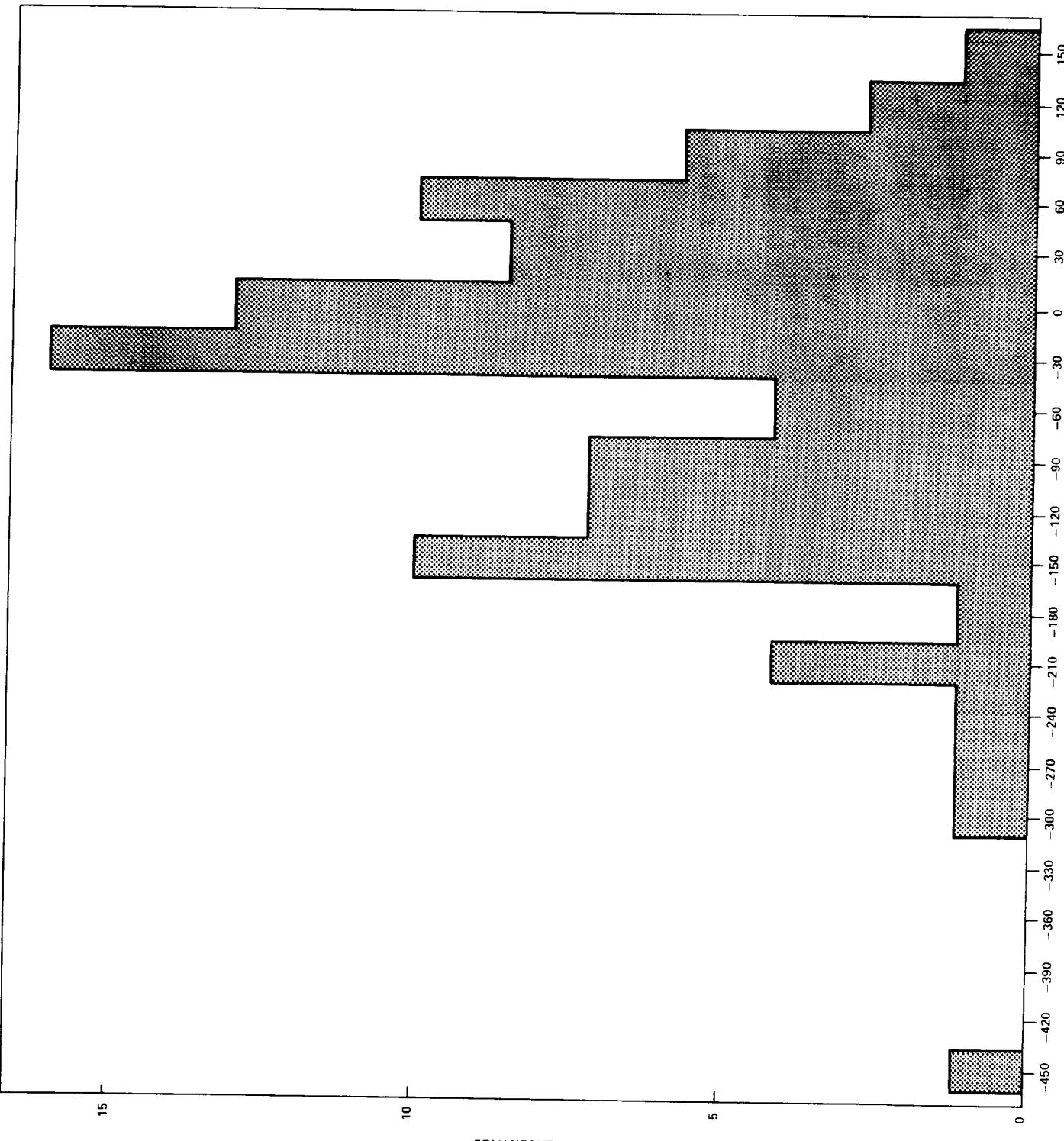


FIGURE 4 - FREQUENCY DISTRIBUTION OF CHANGE IN AVAILABLE SPS CONTINGENCY  $\Delta V$  AS LAUNCH AZIMUTH INCREASES FROM 90 TO 96 DEGREES

CHANGE IN AVAILABLE SPS CONTINGENCY  $\Delta V$  (fps)

FIGURE 5 - FREQUENCY DISTRIBUTION OF CHANGE IN AVAILABLE SPS CONTINGENCY  $\Delta V$  AS LAUNCH AZIMUTH  
INCREASES FROM 72 TO 96 DEGREES



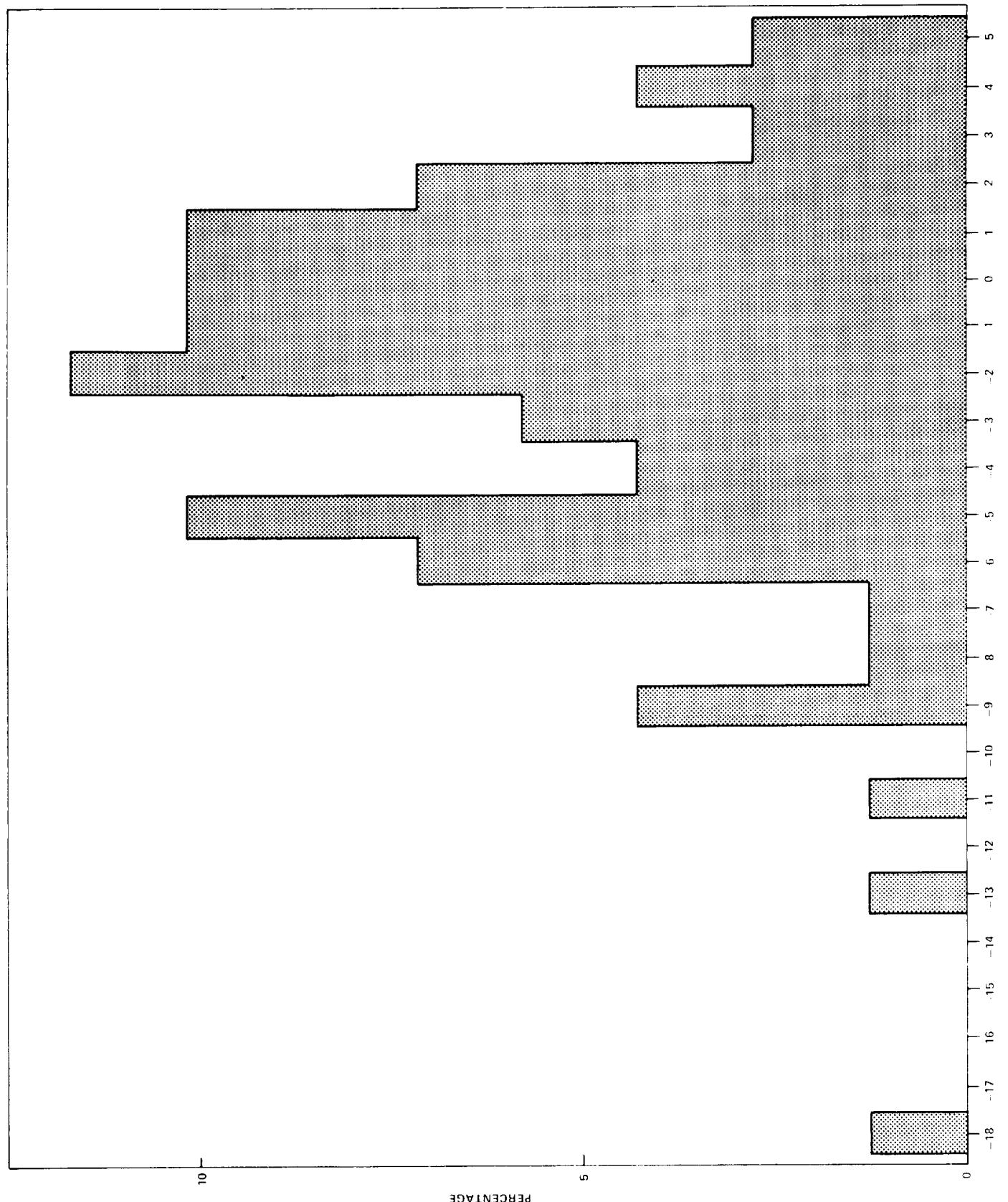


FIGURE 6 FREQUENCY DISTRIBUTION OF CHANGE IN AVAILABLE SPS CONTINGENCY  $\Delta V$  FOR ONE DEGREE OF LAUNCH AZIMUTH CHANGE

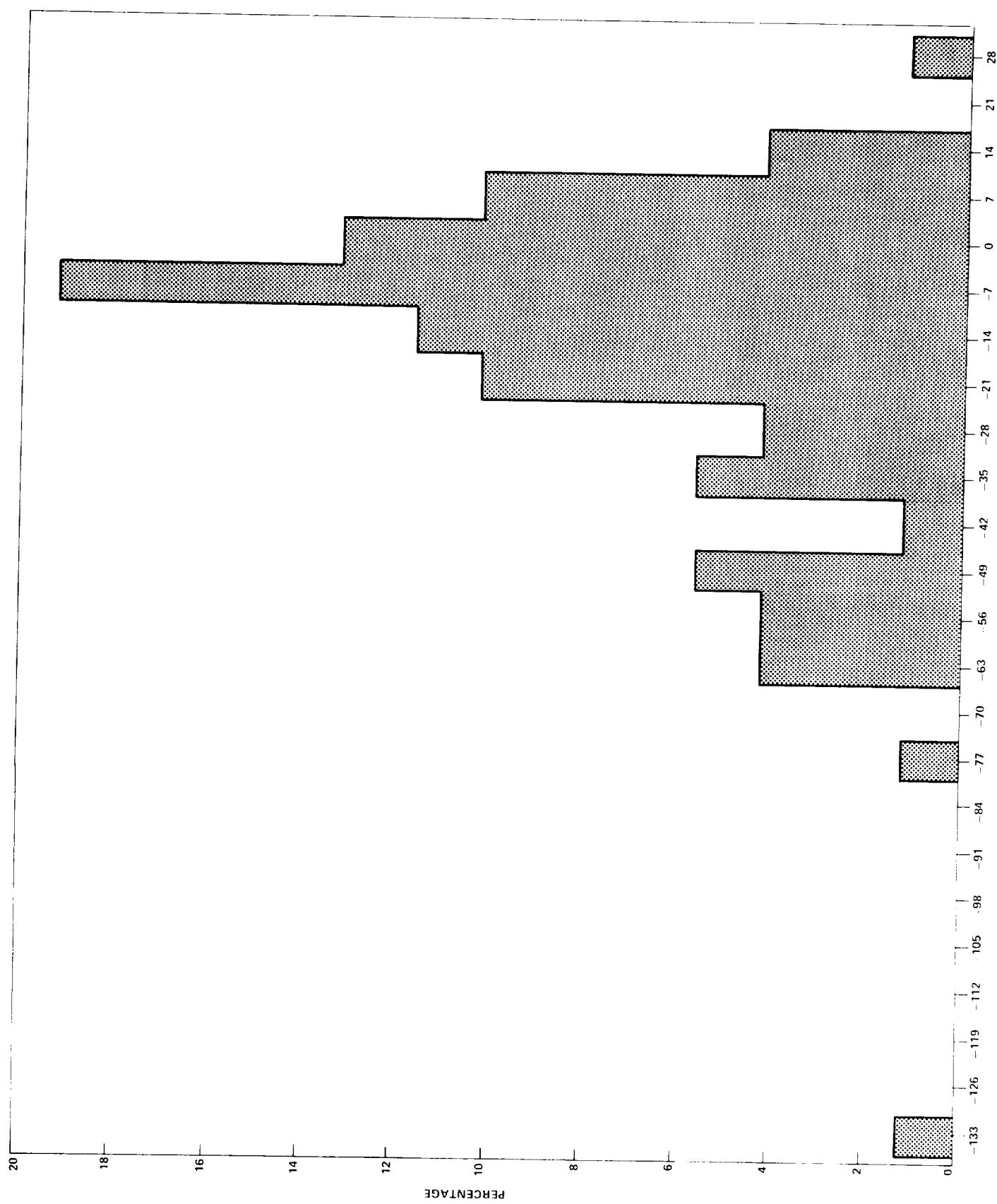


FIGURE 7 FREQUENCY DISTRIBUTION OF CHANGE IN LAUNCH VEHICLE CAPABILITY DUE TO TLI ENERGY REQUIREMENTS AS LAUNCH AZIMUTH INCREASES FROM 72 TO 80 DEGREES

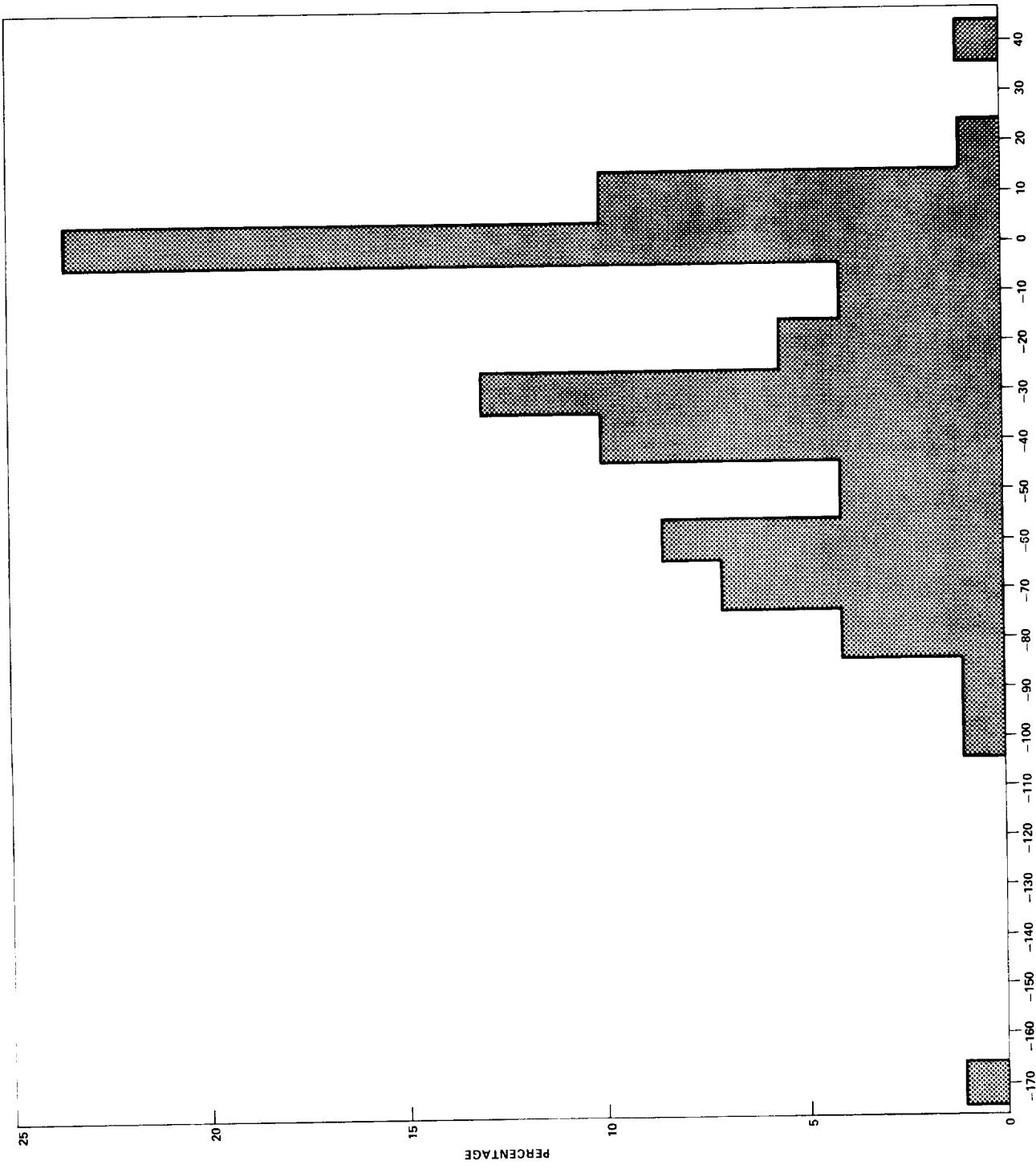


FIGURE 8 - FREQUENCY DISTRIBUTION OF CHANGE IN LAUNCH VEHICLE CAPABILITY DUE TO TLI ENERGY REQUIREMENTS AS LAUNCH AZIMUTH INCREASES FROM 80 TO 90 DEGREES

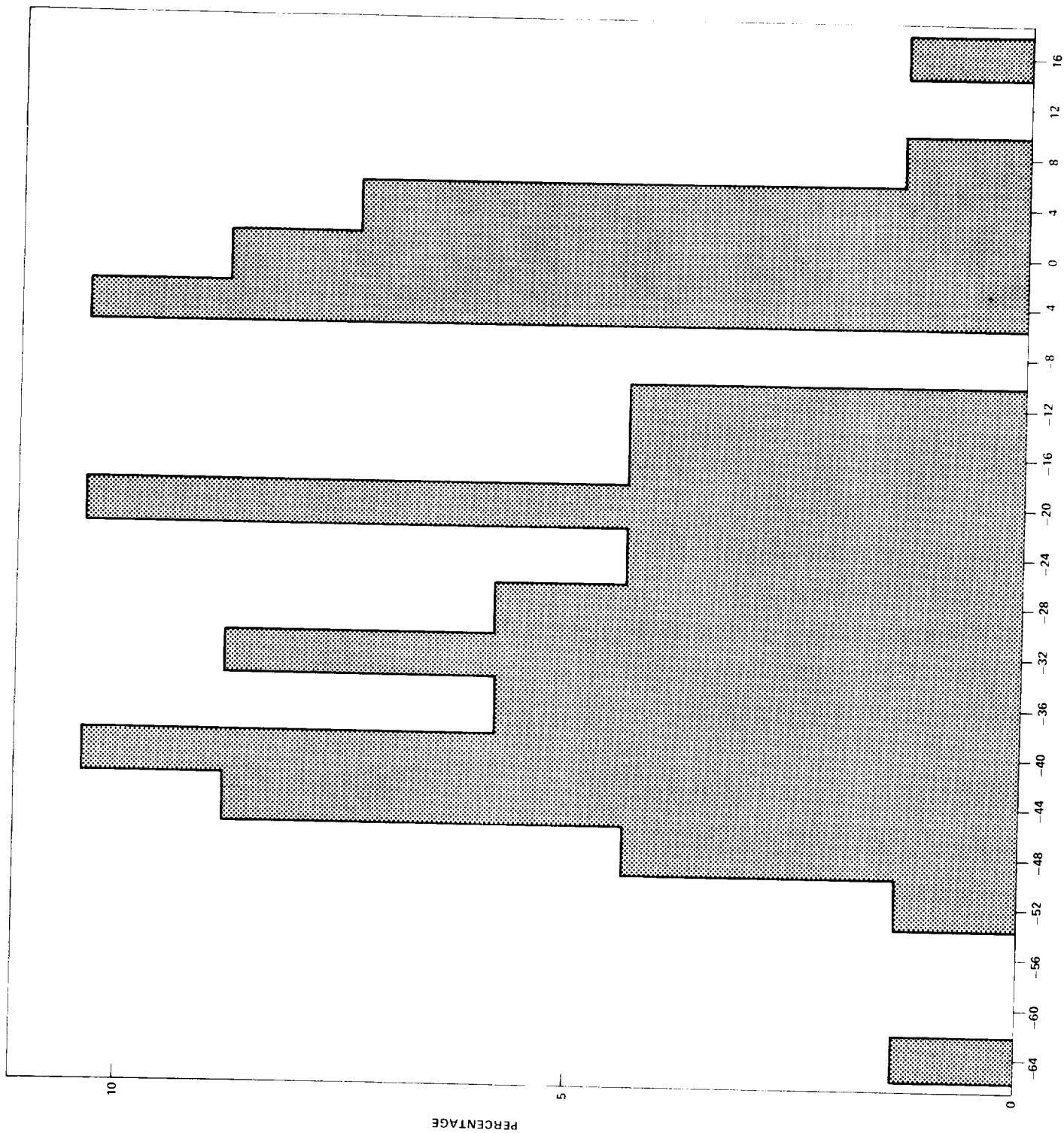


FIGURE 9 FREQUENCY DISTRIBUTION OF CHANGE IN LAUNCH VEHICLE CAPABILITY DUE TO TOTAL ENERGY REQUIREMENTS AS LAUNCH AZIMUTH INCREASES FROM 90 TO 96 DEGREES

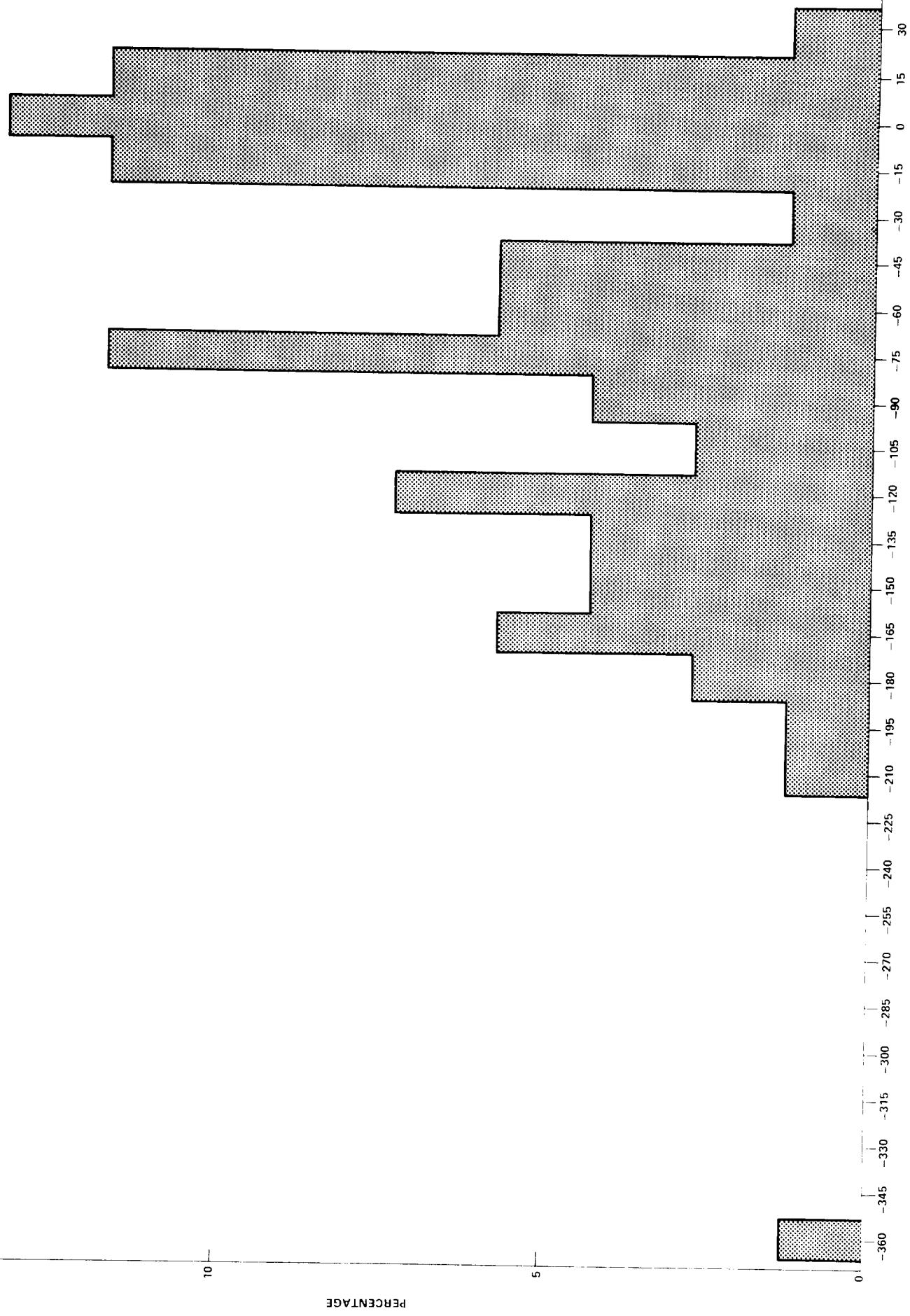


FIGURE 10. FREQUENCY DISTRIBUTION OF CHANGE IN LAUNCH VEHICLE CAPABILITY DUE TO TLI ENERGY REQUIREMENTS AS LAUNCH AZIMUTH INCREASES FROM 72 TO 96 DEGREES

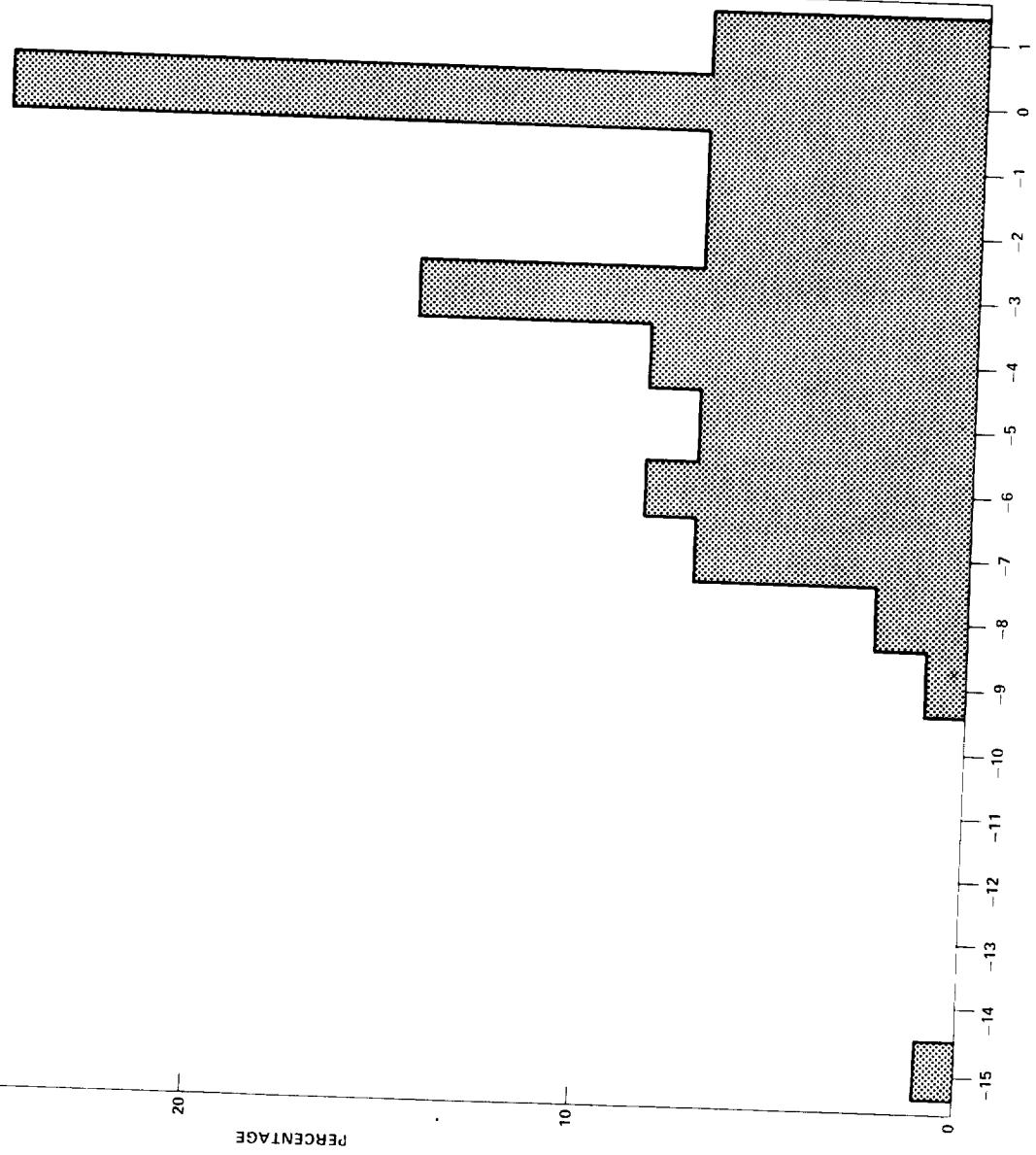


FIGURE 11 FREQUENCY DISTRIBUTION OF CHANGE IN LAUNCH VEHICLE CAPABILITY DUE TO TLI ENERGY REQUIREMENTS FOR ONE DEGREE OF LAUNCH AZIMUTH CHANGE

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